

## Ch 8: Energy, Enzymes, and Metabolism

1. Which of the following statements about ATP are FALSE:

- a) One person uses about 1 kg ATP per day
- b) ATP is the "energy currency" of all cells
- c) Formation of ATP from ADP and Pi requires an input of energy
- d) ATP provides energy for many different biochemical reactions
- e) ATP molecules are used as building blocks for synthesis of some macromolecules

*a) is the only false statement. A person uses about 40 kg ATP per day. This is possible because each ATP molecule is recycled around 10 000 times in a day.*

2. Sketch the structure of ATP, and mark the energy-rich bond that is broken by hydrolysis to release energy.

*See fig 8.5A p. 154.*

*The anhydride bond between the second and third phosphate group is broken, when ATP is hydrolysed to ADP to generate energy.*

3. What is an enzyme? What is the role of enzymes in cells?

*An enzyme is a protein with catalytic properties*

*Enzymes catalyse specific reactions in the cell, that normally would not occur (quickly enough) due to high activation energy. p156-157.*

4. What is the "active site" of an enzyme?

*Active site: The site on the enzyme where substrate binds and catalysis occurs. p157*

5. What is "induced fit"? Give an example of an enzyme catalysed reaction involving induced fit

*Induced fit: The enzyme changes conformation on binding of substrates. The structure is altered such that the enzyme closes around the substrate. This often has the effect of preventing unwanted side-reactions.*

*E.g.  $\text{glucose} + \text{ATP} \rightarrow \text{glucose-6-phosphat} + \text{ADP}$*

*In this case, the induced fit mechanism of hexokinase prevents hydrolysis of ATP by water. p 159, Fig 8.12 p.160*

6. What is a cofactor? Give examples of cofactors.

*Cofactor: Inorganic ions that bind to certain enzymes, often in the active site, and are necessary for function of the enzyme.*

*E.g.  $\text{Mg}^{2+}$ ,  $\text{Ni}^{2+}$ ,  $\text{Zn}^{2+}$ , Mo, Se,  $\text{Mn}^{2+}$ ,  $\text{K}^+$ ,  $\text{Fe}^{2+}/\text{Fe}^{3+}$ ,  $\text{Cu}^{2+}$  (see p160)*

**7. What is a coenzyme? Give examples of coenzymes**

*Co-enzyme: Small organic molecules (often derived from vitamins) that are loosely bound to enzymes and are required for enzyme function. They can often be regarded as "co-substrates"*

*E.g. Biotin, Coenzyme A, NAD<sup>+</sup>, FAD og ATP (see p160)*

**8. Name different ways in which enzymes can be regulated**

*e.g.*

- *Reversible /irreversible inhibition*
- *Allosteric inhibition/activation*
- *pH*
- *Temperature*

**9. Allosteric proteins:**

*a) What are the characteristics of allosteric proteins?*

*Allosteric proteins (in this case enzymes) have regulatory sites distinct from the active sites, and several functional active sites. Most allosteric proteins are composed of more than one subunit. Allosteric proteins can exist in different conformations, one of which is more active than the other. These conformations exist in equilibrium.*

*p162-163.*

*b) Explain how enzymes are regulated by allosteric effectors*

*Allosteric regulators (often small signal molecules) bind to the regulatory site of the enzyme, which causes changes in the enzyme structure, resulting in a stabilization of the more active conformation (allosteric activators) or the less active conformation (allosteric inhibitors).*

**10. What is meant by "feedback inhibition"?**

*Feedback inhibition: The enzyme that catalyses the "committed step" in a metabolic pathway is often inhibited by the end-product of that pathway. This avoids overproduction of the end-product.*

*Fig 8.19 p164.*

**11. Do allosteric enzymes follow the curve for enzyme activity that is shown in Fig. 8.13?**

*Allosteric enzymes do not follow the curve shown in Fig 8.13. They follow a sigmoid "S-shaped" curve when plotting reaction rate against substrate concentration (Fig 8.18B). This is due to cooperativity, which means that binding of substrate to one active site affects the binding to other active sites on the same enzyme. When there is little substrate present, the enzyme will be found almost exclusively in the less-active conformation. Binding of substrate to one active site can stabilize the more-active form. The result is that small changes in substrate concentration can lead to large changes in enzyme activity.*

*p163-164.*

**12.** What is a prosthetic group? Give some examples.

*Prosthetic group: Small organic molecules that are essential for enzyme activity and are covalently bound to the enzyme*

*E.g. Hæm, flavin, retinal (Table 8.1 p160)*

**13.**

a) What do the letters ATP stand for? *Adenosine triphosphate.*

b) What is the function of ATP in the cell? *ATP functions as energy currency*

c) Write a reaction involving ATP as 1) substrate 2) product (formulae not required)

*Substrate: ATP + glucose → glucose-6-phosphate + ADP*

*Product: ADP + Pi → ATP*

**14.** Can addition of a specific enzyme to a chemical mixture...

1) ...cause an endergonic reaction to run?

*Only if there is an exergonic reaction that can be coupled to the endergonic one.*

2) ...cause a spontaneous reaction to run faster?

*Yes. The enzyme can lower the activation energy so a reaction that normally takes years to run to completion can take a few seconds. (p 157-158)*

**15.** What is the difference between reversible and irreversible inhibition?

*Reversible inhibition means that the inhibition is not permanent – the inhibitor binds and can be released again, leaving the enzyme in active state once more. Irreversible inhibition is permanent because the inhibitor binds covalently to the enzyme. p161-162*

**16.** Explain what is meant by a) anabolism, b) catabolism, c) metabolism

*a) Synthesizing (building up) reactions b) Breakdown reactions c) The sum of building-up and breaking-down reactions. p 150.*

**17.** How is it possible for an endergonic reaction to take place in a cell?

*It is possible for an endergonic reaction to run, if it is coupled to an exergonic reaction such as the hydrolysis of ATP. p155.*

**Opagve 18.** Describe briefly why pH is always critical for enzyme catalysed reactions

*pH determines the charge state of amino acid side chains on the surface of the enzyme. The change of amino acid side chains around the active site is often critical for substrate binding and/or catalysis. p165.*

**Exam autumn 2010.**

$\Delta G$  for reaction  $A \rightarrow B$  is  $+11.4 \text{ kJmol}^{-1}$

$\Delta G$  for reaction  $B \rightarrow C$  is  $-22.9 \text{ kJmol}^{-1}$

What is  $\Delta G$  for conversion of  $A \rightarrow C$ ?

$$\Delta G = 11.4 - 22.9 = -11.5 \text{ kJmol}^{-1}$$